

Claims:

1 1. A quadrature oscillator with phase error correction, comprising:
 2 a local oscillator that generates a single-ended clock signal;
 3 a single-ended to differential converter, coupled to the local oscillator, that
 4 converts the single-ended clock signal to a differential clock signal;
 5 a quadrature generator, coupled to the converter, that converts the differential
 6 clock signal into an in-phase (I) carrier signal and a quadrature (Q) carrier signal;
 7 a phase error detector, coupled to the quadrature generator, that measures a phase
 8 error between the I and Q carrier signals and that provides a phase error signal; and
 9 a feedback amplifier, coupled to the phase error detector and the quadrature
 10 generator, that modifies the differential clock signal based on measured phase error.

1 2. The quadrature oscillator of claim 1, wherein the single-ended to
 2 differential converter includes a second stage that generates a pair of differential clock
 3 signals.

1 3. The quadrature oscillator of claim 1, wherein the quadrature generator
 2 divides the frequency by two.

1 4. The quadrature oscillator of claim 1, wherein the feedback amplifier
 2 applies the measured phase error as a DC offset to an AC differential clock signal.

1 5. The quadrature oscillator of claim 1, further comprising:
 2 the local oscillator asserting the single-ended clock signal as a voltage signal;
 3 the single-ended to differential converter asserting the differential clock signal as
 4 a differential voltage signal;

5 a transconductor, coupled to the single-ended to differential converter and the
6 quadrature generator, that converts the differential clock voltage signal into two pairs of
7 differential current clock signals; and

8 the quadrature generator comprising a master-slave latch configuration, coupled
9 to the transconductor, that generates I and Q current signal outputs from the two pairs of
10 differential current clock signals.

1 6. The quadrature oscillator of claim 5, wherein the transconductor
2 comprises:

3 a dual pair of common-emitter coupled transistors, each pair having a base input
4 receiving a component of the differential clock signal and each pair having a pair of
5 collectors generating a corresponding one of the two pairs of differential current clock
6 signals; and

7 a current source coupled between the emitters of each of the dual pair of
8 transistors and ground.

1 7. The quadrature oscillator of claim 5, further comprising:

2 a first chain of buffers that amplifies the I current signal output to provide the I
3 carrier signal; and

4 a second chain of buffers that amplifies the Q current signal output to provide the
5 Q carrier signal.

1 8. The quadrature oscillator of claim 7, wherein the phase error detector
2 generates a phase error voltage indicative of phase error between the I and Q carrier
3 signals.

1 9. The quadrature oscillator of claim 8, wherein the feedback amplifier
2 comprises:

3 a transconductance stage, coupled to the phase error detector and the quadrature
4 generator, that converts a phase error voltage into a correction current and that adds the
5 correction current to each of the two pairs of differential current clock signals.

1 10. The quadrature oscillator of claim 9, wherein the transconductance stage
2 comprises MOSFET current sources.

3 11. The quadrature oscillator of claim 9, wherein the feedback amplifier
4 further comprises:

5 an RC filter, coupled to the phase error detector; and

6 an amplifier stage, coupled to the RC filter and the transconductor stage, that
7 amplifies the phase error voltage.

1 12. The quadrature oscillator of claim 1, wherein the phase error detector
2 comprises:

3 a first mode buffer, coupled to the quadrature generator, that generates first mode
4 I and Q carrier signals;

5 a second mode buffer, coupled to the quadrature generator, that generates second
6 mode I and Q carrier signals;

7 a first phase error detector that measures a phase error between the first mode I
8 and Q carrier signals and that provides a first mode phase error signal;

9 a second phase error detector that measures a phase error between the second
10 mode I and Q carrier signals and that provides a second mode phase error signal; and

11 a mode switch, coupled to the first and second phase error detectors and the
 12 feedback amplifier, that couples the first phase error detector to the feedback amplifier in
 13 a first mode and that couples the second phase error detector to the feedback amplifier in
 14 a second mode.

11 12 13 14

1 13. A quadrature local oscillator with phase error correction, comprising:

2 a single-ended to differential converter that converts a single-ended clock signal

3 to a differential clock signal;

4 a transconductor, coupled to the single-ended to differential converter, that

5 converts the differential clock signal into a pair of differential clock signals;

6 a quadrature generator, coupled to the transconductor, that converts the pair of

7 differential clock signals into an in-phase (I) clock signal and a quadrature (Q) clock

8 signal;

9 a first chain of buffers, coupled to the quadrature generator, that develops an I

10 carrier signal as a corrected version of the I clock signal, the first chain of buffers having

11 an intermediate feedback junction;

12 a second chain of buffers, coupled to the quadrature generator, that develops a Q

13 carrier signal as a corrected version of the Q clock signal, the second chain of buffers

14 having an intermediate feedback junction;

15 a phase error detector, coupled to the first and second chain of buffers, that

16 measures a phase error between the I and Q carrier signals and that provides a phase error

17 signal;

18 a feedback amplifier, coupled to the phase error detector, that receives the phase

19 error signal and that generates a differential feedback signal; and

20 a pair of tuning elements, each coupled to the feedback amplifier and a respective

21 one of the intermediate feedback junctions of the first and second chain of buffers.

1 14. The quadrature local oscillator of claim 13, wherein each of the pair of

2 tuning elements comprises a tunable RC circuit.

- 1 15. The quadrature local oscillator of claim 13, wherein each of the pair of
- 2 tuning elements comprises:
- 3 a series resistance coupled between successive buffers of the chain of buffers; and
- 4 a tunable varactor coupled to the resistance and the feedback amplifier.

11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 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1 16. A quadrature oscillator with phase error correction, comprising:
 2 a clock generator that provides a clock signal;
 3 a clock splitter, coupled to the clock generator, that splits the clock signal into
 4 first and second clock signals;
 5 a first phase shifting network, coupled to the clock splitter, that develops a first
 6 carrier signal based on the first clock signal;
 7 a second phase shifting network, coupled to the clock splitter, that develops a
 8 second carrier signal based on the second clock signal, wherein the second clock signal
 9 intended to be one quarter phase shifted relative to the first carrier signal; and
 10 a phase detector, coupled to the first and second phase shifting networks, that
 11 asserts a phase error signal used to control the phase shifting networks.

1 17. The quadrature oscillator of claim 16, further comprising:
 2 a combiner, coupled to the phase detector and the clock splitter, that adjusts the
 3 first and second clock signals based on the phase error signal.

1 18. The quadrature oscillator of claim 16, further comprising:
 2 the first and second phase shifting networks each developing a respective one of
 3 first and second intermediate carrier signals; and
 4 a combiner, coupled to the phase detector and the first and second phase shifting
 5 networks, that adjusts the first and second intermediate carrier signals based on the phase
 6 error signal.

1 19. A method of generating quadrature signals with phase error correction,
2 comprising:
3 generating a clock signal;
4 converting the clock signal into a differential clock signal;
5 splitting the clock signal into first and second clock signals;
6 developing an in-phase (I) differential carrier signal and a quadrature phase (Q)
7 differential carrier signal based on the first and second clock signals;
8 detecting phase error between the I and Q differential carrier signals and
9 generating a phase error feedback signal; and
10 adjusting the phase differential between the I and Q differential carrier signals
11 based on the phase error feedback signal.

1 20. The method of claim 19, wherein the adjusting the phase differential
2 comprises combining the phase error feedback signal with the first and second clock
3 signals.

1 21. The method of claim 19, further comprising:
2 generating intermediate I and Q differential carrier signals within a chain of
3 buffers; and
4 the adjusting the phase differential comprises combining the phase error feedback
5 signal with the intermediate I and Q differential carrier signals.